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(71) Applicants
Rolls-Royce Limited, 65 Buckingham Gate, London, SW1E 6AT
(72) Inventor
Raymond Dinsdale
(74) Agent
G. T. Kelvie, Company Patents & Licensing Dept., Rolls-Royce Limited, P.O. Box 31, Moor Lane, Derby, DE2 8BJ

(54) **Blade twisting**

(57) A method for twisting a blade, e.g. of a ducted fan gas turbine engine, comprises putting the blade 10 in a machine 12, which grips the blade root in dies 14, 16 and receives the blade tip in a slot 22 in a rotary member 20. The blade is heated to ease plastic deformation and then the rotary member 20 is rotated in steps, pausing between each step. The blade is thus creep formed into a twisted shape.

Fig.2.

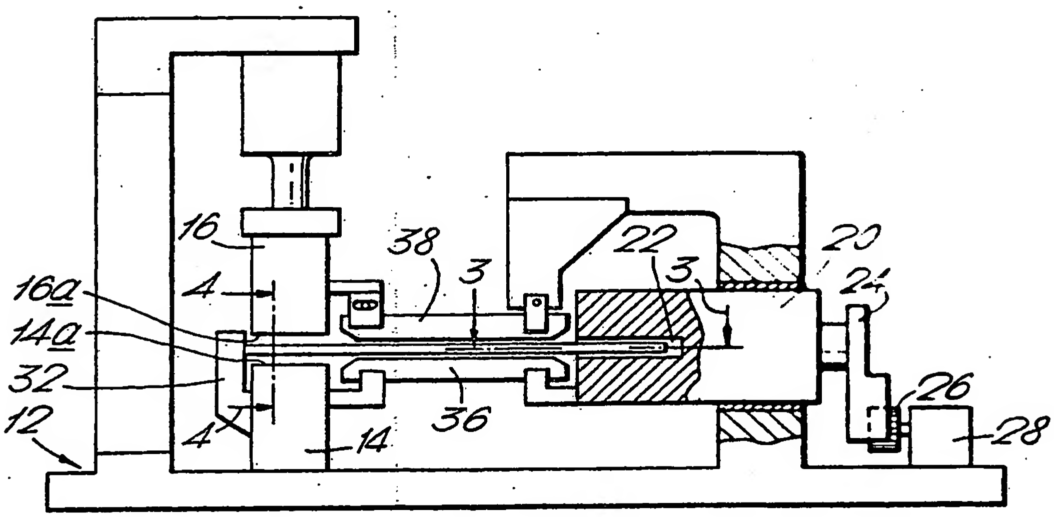

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Fig.1.

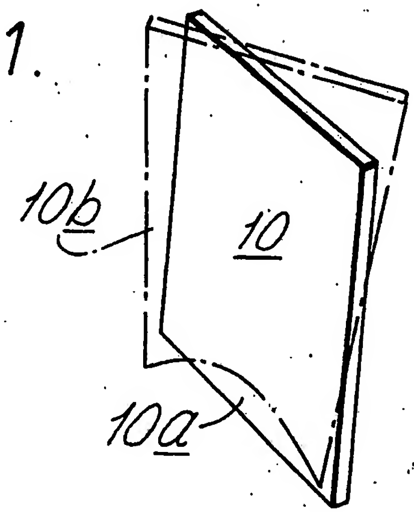


Fig.3.

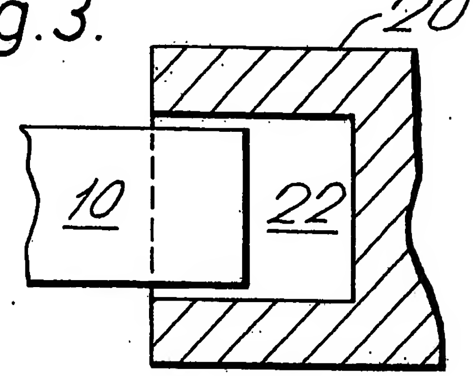


Fig.2.

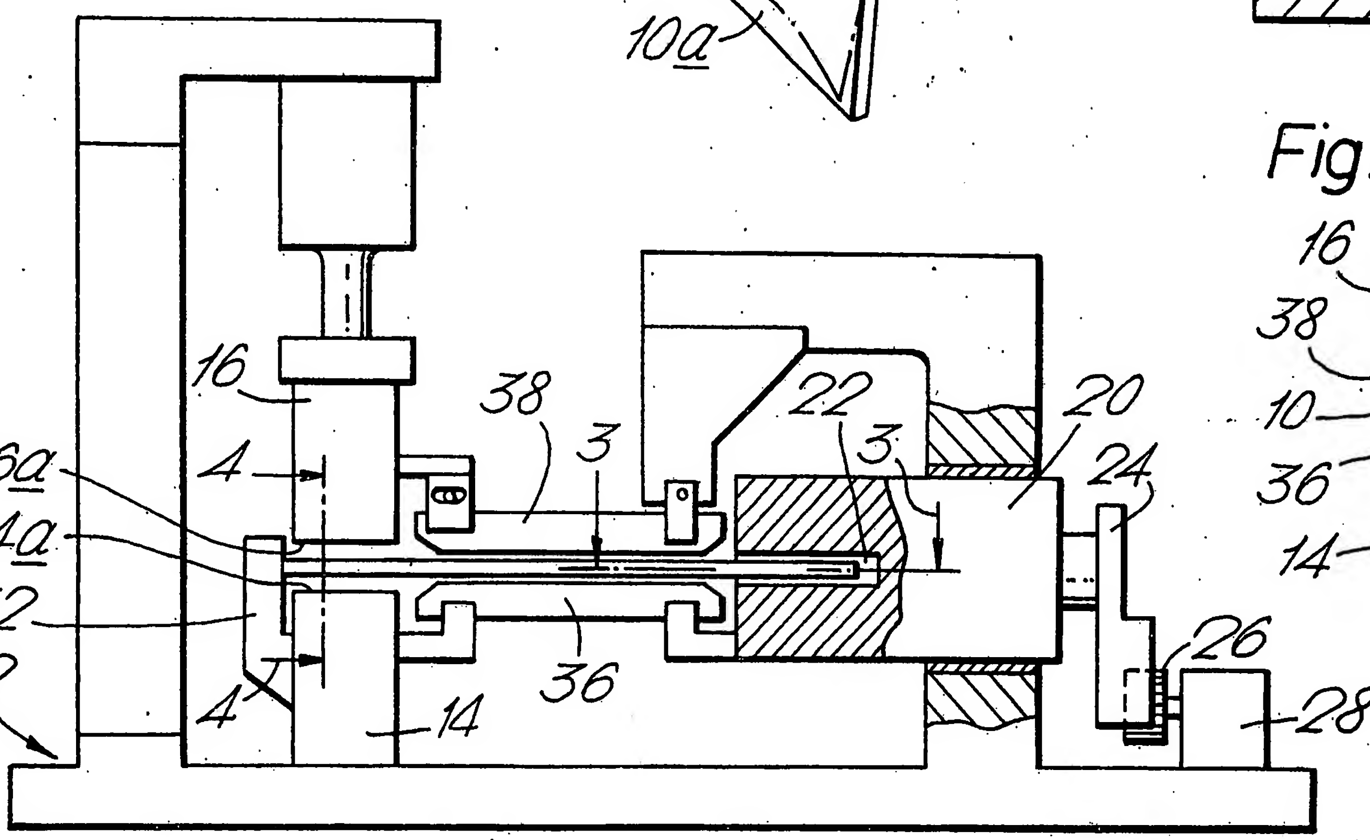
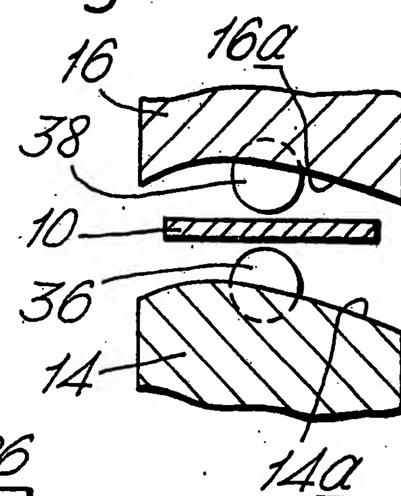


Fig.4.



SPECIFICATION

Method f and apparatus for twisting fluid driv blades

The present invention is concerned with the twisting of a metal member such that if the member is appropriately positioned in a fluid and rotated, it will displace the fluid in a direction normal to the plane of rotation.

The present invention further concerns apparatus for achieving said twist.

Accordingly, the present invention provides a method of twisting a metal, fluid drive blade, including the steps of placing the blade in apparatus which grips one end thereof and receives the other end in a slot, the ends of which are spaced from the respective blade edges, heating the blade so as to ease plastic deformation and, rotating that part of the apparatus which contains the slot, so as to cause the longer sides of the slot to engage the flank of the blade and twist it.

Preferably the method includes the steps of rotating that part of the apparatus which contains the slot, in increments of the total desired rotation, and holding the position reached after each incremental rotation so as to allow the blade to adopt a desired twist by creep forming.

Preferably, the method further includes the step of heating the apparatus prior to insertion of the blade, then after insertion of the blade, allowing a given time for the blade to become heated *via* the apparatus and atmosphere, before gripping and twisting it.

The method may include the step of forming a camber on the gripped end of the blade, by forces generated by the gripping action.

The method may further include the step of forming a camber, the profile of which comprises differing radii of arcs.

The method may include the step of supporting the blade against buckling in a plane chordally of the blade.

Preferably the supporting method includes the step of arranging a rigid member closely adjacent each blade flank, in a position intermediate and parallel with, the blade leading and trailing edges, so as to constrain movement of the blade in said plane.

The invention also comprises a blade twisting machine tool comprising, a body supporting means for gripping a blade root, a rotary member which includes a slot, which is aligned with the gripping means so as to enable the free end of a blade which is gripped, to be inserted in the slot, means for rotating said rotary member and, heating means for heating the blade prior to heating.

Preferably the gripping means comprises relatively movable die portions which are so shaped as to form a camber on the blade root when gripping it.

A blade twisting machine tool as claimed in claim 9 or 10 wherein the means for rotating the rotary member may comprise a quadrant driven by a motor mounted gear wheel.

Means may be provided for supporting a blade being twisted, against buckling in a plane normal to the plane of twisting.

Preferably, the means comprises a pair of rigid rods which in operation, are held closely adjacent each flank of a blade, at a position intermediate and parallel with, the blade leading and trailing edges.

Preferably, the heating means comprises a furnace.

The invention will not be described by way of example and with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic view of a fluid drive blade before and after twisting by the method of the present invention,

Figure 2 is a part cross sectional side view of a machine tool in accordance with the invention,

Figure 3 is a view on line 3—3 of Figure 2, and

Figure 4 is a view on line 4—4 of Figure 2.

In Figure 1 a fluid drive blade is indicated by the numeral 10. In the particular example, the blade 10 is in the form of a flat metal sheet which is intended for use as a fan blade for a ducted fan, gas turbine engine.

In practice, either one such sheet may be utilised, to form into a solid fan blade or, alternatively, two such sheets may be employed, at least one of them having a hollow machined in a flank, which is then joined by e.g. brazing to the other sheet, to form a hollow fan blade.

Still referring to Figure 1, the solid outline 10*a* depicts the sheet 10 prior to twisting and, the chain dotted outline depicts the sheet after twisting, in accordance with the present invention.

Referring now to Figure 2. A frame 12 at one end carries a pair of relatively movable dies 14, 16. Die 16 reciprocates vertically so as to grip or release that end of a sheet 10, which eventually forms the root of the finished article. If a straight root portion is required, dies 14, 16 will act as a simple vice mechanism. If, however, the blade is to have a cambered root portion, then dies 14, 16 will be provided with appropriately shaped gripping surfaces 14*a*, 16*a* as in the present example.

The other end of frame 12 supports a rotary member 18 which although shown as being supported in a plain hearing shell 20, could of course be supported for rotation on more sophisticated bearing structures if desired.

Rotary member 18 has a slot 22 formed in that end nearest dies 14, 16 and the width of the slot is sufficient to easily accept the thickness of metal sheet blade 10 whilst its length is sufficient to accept the width of the metal sheet blade 10 and provide a clearance between each edge of the blade, for reasons explained later in this specification.

In the present example, a quadrant 24 is fastened to th rotary member 20 and is connected *via* a step down gear 26, to a motor 28.

For op ration, the whole f the apparatus is enclosed in a furnace and brought up to the

temperatures at which the blade may be cambered and/ r twisted. Th furnace is represented in Figure 2, by a dotted line 30 it being understood, that the furnace may be a standard piece of equipment. H wever, it must take operating loads of up to 30 tons (3045 kg).

The blade material of the present invention is Titanium alloy and it has been found that heating the material to about 700°C, prior to cambering and twisting, gives the best results.

In the prepared embodiment of the invention the operation is performed in a number of steps, so that the camber and twist are creep formed, i.e. a first load is applied and held, until the material changes its shape to the extent that the load is nullified. A further load is then applied and held and so on, until the blade has finally adopted the desired shape.

A typical and preferred series of steps which are taken, so as to achieve the desired form, are given hereinafter:

1. Preheat apparatus to about 500°C.

2. Load sheet blade 10 into the apparatus, ensuring that the extreme root ends abuts stop member 32 and apply a retaining load on the root *via* the dies 14—16.

3. Close furnace and heat to and maintain at 700°C.

4. Move dies through half a working stroke, so as to partially form camber on blade root and maintain for 5 minutes.

5. Fully close the dies 14, 16 so as to fully form the desired camber on the root, and hold for 5 minutes.

6. Maintain dies 14—16 in fully closed positions and move quadrant to a first position and hold for 2 minutes.

7. Move quadrant to a second position and hold for 2 minutes.

8. Move quadrant to a third position and hold f r 2 minutes.

9. Move quadrant to a fourth position and hold for 2 minutes.

10. Move quadrant to a fifth position and hold for 2 minutes.

11. Move quadrant to a sixth final position and hold for 5 minutes.

12. Open dies, return quadrant to rest and remove blade from furnace.

An alternative method is as follows:

Steps 1 to 3 as described hereinbefore, then:

4. Apply a first forming load on the blade root, *via* the dies 14, 16 which of course grip the blade root as a result of the said loading and, at the same time, applying a first twisting load to the blade tip *via* the walls of slot 22, by rotating quadrant 24 through an arc, t a first position. Hold the dies and quadrant in their respective positions for 5 minutes.

5. Move dies 14, 16 and quadrant 24 to second positions and hold for 2 minutes.

6. Move dies 14, 16 and quadrant 24, to third positions and hold for 3 minutes.

7. Maintain dies 14, 16 in position mentioned at 6 above, and move quadrant 24 to a final twisting position and hold for 3 minutes.

8. Return di s 14, 16 and quadrant 24 to their non-operative positions, open furnace and remove formed sheet blade 10.

Experiment has shown, that during twisting of the blade, the leading and trailing edges stretch by differing amounts, whilst the central portion of the blade, along its length attempts to compress. However, this latter phenomenon results in buckling of the blade at a chordal position near the camber run out/twisted portion interface.

In order to constrain blade 10 against buckling a pair of rods 34, 36 are positioned closely adjacent each side of the blade, and extend over the greater portion of the length of the blade centre line.

Rod 36 is supported from the movable die 16, being connected thereto by a slot and pin arrangement 38. The other end of rod 38 is hinged to the structure supporting rotary member 20. Rod 38 can thus be pivoted upwards to facilitate loading and unloading of a blade 10. Rod 26 is supported so as to maintain the one position shown, through the operation.

As mentioned hereinbefore, the leading and trailing edges of blade 10, stretch unequally, during the cambering and twisting operation. The asymmetric loading experienced by the blade is brought about by the deliberately asymmetrical form of the camber which is required for aerodynamic reasons, distributing the stresses which are put into the blade by the twisting action, more along one edge than the other.

The difference in magnitude of the asymmetric stressing is such that, if the blade material did not stretch as described, the blade would probably be tipped to one side in the dies 14—16, with the result that the twist will not be formed about a line longitudinally of the blade and which is in correct angular relationship with the blade root portion which lies between the dies. The stretching therefore, is enabled by way of closing the ends of slot 22 so that movement of the blade in a sideways direction, is all but prevented, and ensuring that the blade is a sliding fit in the slot.

If the blade root is fully gripped and therefore, fully formed, before twisting, then on twisting, the loading and trailing edges of the blade stretch by substantially different amounts e.g. in the ratio of 3:1. However, the magnitude of difference depends on the root camber radii and, angle of twist in the blade. If the root is a straight root, gripping does not affect the blade in such an adverse manner, i.e. the magnitude of stretching of the leading and trailing edges of the blade, are substantially identical.

The invention has been described in connection with the cambering and twisting of what is, in effect, a flat metal plate. However, the invention is equally efficacious, in the twisting of the aerofoil portion of a blade which has been pre-forged to substantially finish size dimensions. In such a blade, the aerofoil leading and trailing edges are much thinner than the central portion of the aerofoil and it has been prov d by experiment, that

the consequently different thicknesses, are in themselves sufficient to allow the aerofoil to twist without buckling. When twisting the aerofoils of such blades, rods 36, 38 may therefore be dispensed with.

CLAIMS

1. A method of twisting a metal, fluid drive blade, including the steps of placing the blade in apparatus which grips one end thereof and receives the other end in a slot, the ends of which are spaced from the respective blade edges, heating the blade so as to ease plastic deformation and, rotating that part of the apparatus which contains the slot, so as to cause the longer sides of the slot to engage the flanks of the blade and twist it.

2. A method of twisting a metal, fluid drive blade as claimed in claim 1 including the steps of rotating that part of the apparatus which contains the slot, in increments of the total desired rotation, and holding the position reached after each incremental rotation so as to allow the blade to adopt a desired twist by creep forming.

3. A method of twisting a metal fluid drive blade as claimed in claim 1 or 2, including the step of heating the apparatus prior to insertion of the blade, then after insertion of the blade, allowing a given time for the blade to become heated *via* the apparatus and atmosphere, before gripping and twisting it.

4. The method of twisting a metal, fluid drive blade as claimed in any previous claim, including the step of forming a camber on the gripped end of the blade, by forces generated by the gripping action.

5. The method of twisting a metal, fluid drive blade as claimed in claim 4 including the step of forming a camber, the profile of which comprises differing radii of arcs.

6. A method of twisting a metal, fluid drive blade as claimed in any previous claim including the step of supporting the blade against buckling in a plane chordally of the blade.

7. A method of twisting a metal, fluid drive blade as claimed in claim 6 including the step of arranging a rigid member closely adjacent each blade flank, in a position intermediate and parallel with, the blade leading and trailing edges, so as to constrain movement of the blade in said plane.

8. A method of twisting a metal, fluid drive blade, substantially as described in this specification, with reference to the drawings.

9. A blade twisting machine tool comprising, a body supporting means for gripping a blade ro t, a rotary member which includes a slot which is aligned with the gripping means so as to enable the free end of a blade which is gripped, to be inserted in the slot, means for rotating said rotary member and, heating means for heating the blade prior to twisting.

10. A blade twisting machine tool as claimed in claim 10 wherein the gripping means comprises relatively movable die portions which are so shaped as to form a camber on the blade root when gripping it.

11. A blade twisting machine tool as claimed in claim 9 or 10 wherein the means for rotating the rotary member comprises a quadrant driven by a motor mounted gear wheel.

12. A blade twisting machine tool as claimed in any of claims 9 to 11 including means for supporting a blade being twisted, against buckling in a plane chordally of the blade.

13. A blade twisting machine tool as claimed in claim 12 wherein said means comprises a pair of rigid rods which in operation, are held closely adjacent each flank of a blade, at a position intermediate and parallel, with the blade leading and trailing edges.

14. A blade twisting machine as claimed in any previous claim, wherein the heating means comprises a furnace.

15. A blade twisting machine substantially as described in this specification, with reference to the drawings.

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